INDOOR AIR QUALITY ASSESSMENT

Allen Avenue School
290 Allen Avenue
North Attleborough, MA

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program

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Background/Introduction

At the request of the Richard Smith, Superintendent, North Attleborough School Department, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health's (CEH), Bureau of Environmental Health Assessment (BEHA) was asked to provide assistance and consultation regarding indoor air quality in each of North Attleborough public schools. On October 21, 2004, Cory Holmes, an Environmental Analyst in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program, conducted an indoor air quality assessment at the Allen Avenue School (AAS), 290 Allen Avenue, North Attleborough, Massachusetts.

The AAS is a single-story, red brick building that was constructed in 1951. Two portable classrooms were added in the mid 1990s. The building has a history of roof leaks and water damage. Roof repairs were reportedly completed one week prior to the BEHA assessment. Original wooden sash windows are openable throughout the building and are on a capital repair list, since many are reportedly difficult to operate.

Methods

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity were taken with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID). BEHA staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The school houses approximately 220 kindergarten through fourth grade students with approximately 30 staff members. Tests were taken under normal operating conditions and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) parts of air in eighteen of twenty areas surveyed. These results indicate inadequate air exchange in the majority of areas throughout the school on the day of the assessment. Fresh air in classrooms is supplied by unit ventilator (univent) systems (Picture 1). A univent is designed to draw air from outdoors through a fresh air intake located on the exterior wall of the building (Picture 2) and returns air through an air intake located at the base or side of the unit (Figure 1). Fresh and return air are mixed and filtered, then heated and provided to classrooms through an air diffuser located in the top of the unit. Univents are equipped with fan control settings of low, medium or high (Picture 3). Univents are reportedly original equipment, approximately 50-55 years old. Univents of this age can be difficult to maintain because replacement parts are often unavailable. Several univents were found deactivated during the assessment. Obstructions to airflow, such as papers and books stored on univents and bookcases, carts and desks near univent returns, were also seen in several classrooms. In order for univents to provide fresh air as designed, they must remain activated and allowed to operate while rooms are occupied. Intakes and air diffusers must also remain free of obstructions.

Exhaust ventilation in classrooms was originally provided by ducted, grated wall vents powered by rooftop wind turbines (Pictures 4 and 5). Many of these wall vents were obstructed at the time of the assessment (Picture 6). The turbine-driven wall exhausts are supplemented by vents located in the ceilings of coat closets (Picture 7), which are also powered by non-mechanical rooftop wind-driven turbines. Air is drawn into the coat closet from the classroom via undercut closet doors and removed from the building (Picture 8). Neither the wall nor closet vents were drawing air during the assessment. In addition, the location of the vents in the closet allows them to be easily blocked by stored materials (Picture 7). As with the univents, in order to function properly, exhaust vents must be free of obstructions.

Mechanical ventilation for modular classrooms is provided by AHUs mounted on the exterior of each classroom (Picture 9). Fresh air is distributed to classrooms via a wall-mounted air diffuser and drawn back to the AHUs through a wall-mounted return vent (Picture 10). Thermostats control each heating, ventilating and air conditioning (HVAC) system and have fan settings of "on" and "automatic". Thermostats were set to the "automatic" setting (Picture 11) in both of the modular rooms surveyed during the assessment. The automatic setting on the thermostat activates the HVAC system at a preset temperature. Once the preset temperature is reached, the HVAC system is deactivated. Therefore, no mechanical ventilation is provided until the thermostat re-activates the system.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a univent and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools because a majority of occupants is young and considered a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information on carbon dioxide see Appendix A.

Temperature readings ranged from 70^{o} F to 80^{o} F, which were within the BEHA recommended comfort guidelines in all but one area, the computer room. The BEHA recommends that indoor air temperatures be maintained in a range of 70 ^{o} F to 78 ^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., univents not activated, exhaust vents obstructed/not drawing).

The relative humidity measurements ranged from 37 to 55 percent, which were within or close to the lower end of the BEHA recommended comfort range. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity would be expected to drop below comfort levels during the heating season. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Spaces between the sink countertop and backsplash were noted in several classrooms. Improper drainage or sink overflow can lead to water penetration moistening countertop wood, the cabinet interior and behind the cabinets. Like other porous materials, if these materials become wet repeatedly they can provide a medium for mold growth. Mold growth was observed and musty odors were detected in classroom 1. These odors appeared to be produced by the backsplash, which had become water damaged from repeated exposure to moisture (Picture 12).

The US Environmental Protection Agency and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy porous materials is not recommended.

Plants were noted in several classrooms. Plants can be a source of pollen and mold, which can be respiratory irritants for some individuals. Plants should be properly maintained and equipped with drip pans. Plants should also be located away from univents to prevent the aerosolization of dirt, pollen or mold.

Other Concerns

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were non-detect or ND (Table 1). Carbon monoxide levels measured in the school were also ND.

The US EPA also established NAAQS for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits for particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter (μg/m^3) in a 24-hour average (US EPA, 2000a). This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particulate levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 13 $\mu g/m^3$ (Table 1). PM2.5 levels measured indoors ranged from 5 to 30 $\mu g/m^3$. Although PM2.5 measurements were above background in some areas, they were below the NAAQS of 65 $\mu g/m^3$. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were ND (Table 1). Indoor TVOC measurements throughout the building were also ND.

Please note, that the TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. While no measurable TVOC levels were detected in the indoor environment, VOC-containing materials were noted. Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat. -

Several other conditions that can affect indoor air quality were noted during the assessment. Univents in the original building had accumulated dust, cobwebs and debris within the air handling chambers and on filters (Picture 13). Also of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to prevent excessive dust build up. Dust can be irritating to eyes, nose and respiratory tract.

In an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs (Picture 14). Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and cause TVOCs to off-gas. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998). In many areas, alternative "glides" are used on chair legs (Picture 15). School officials reportedly ordered more glides to replace tennis balls.

Conclusions/Recommendations

The conditions related to indoor air quality problems at the AAS raise a number of issues. The general building conditions, maintenance, work hygiene practices and the condition of HVAC equipment, if considered individually, present conditions that could degrade indoor air quality. When combined, these conditions can serve to further degrade indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons, a two-phase approach is required for remediation. The first consists of **short-term** measures to improve air quality and the second consists of **long-term** measures that will require planning and resources to adequately address the overall indoor air quality concerns.

The following **short-term** measures should be considered for immediate implementation:

1. Examine each univent for function. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers throughout the AAS.

2. Operate all ventilation systems that are operable throughout the building (e.g., gym, auditorium, classrooms) continuously during periods of school occupancy and independent of thermostat control. To increase airflow in classrooms, set univent controls to "high".
3. Set the thermostats for modular classrooms to the fan "on" position to operate the ventilation system continuously during the school day.
4. Remove all blockages from univents and exhaust vents to ensure adequate airflow.
5. Consider having ventilation systems re-balanced every five years by an HVAC engineering firm.
6. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
7. Replace water damaged wooden splashboard in classroom 1. Examine behind and around this areas for microbial growth. Disinfect areas of water leaks with an appropriate antimicrobial.
8. Ensure roof leaks are repaired and repair/replace any remaining water-stained ceiling tiles.
9. Ensure plants have drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary.

10. Change filters for univents and window-mounted air conditioners as per the manufacturer's instructions or more frequently if needed. Vacuum interior of units prior to activation to prevent the aerosolization of dirt, dust and particulates.
11. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
12. Consider discontinuing the use of tennis balls on chairs to prevent latex dust generation**.** Continue with plans to purchase "glides".
13. Consider adopting the US EPA (2000b) document, "Tools for Schools", to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at: http://www.epa.gov/iaq/schools/index.html.
14. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

The following **long-term measures** should be considered:

1. Continue with plans to replace/repair window systems throughout the building to prevent water penetration and drafts through window frames.
2. Contact an HVAC engineering firm to determine if wind-driven turbines on the roof can be retrofitted with modern mechanical exhaust motors.

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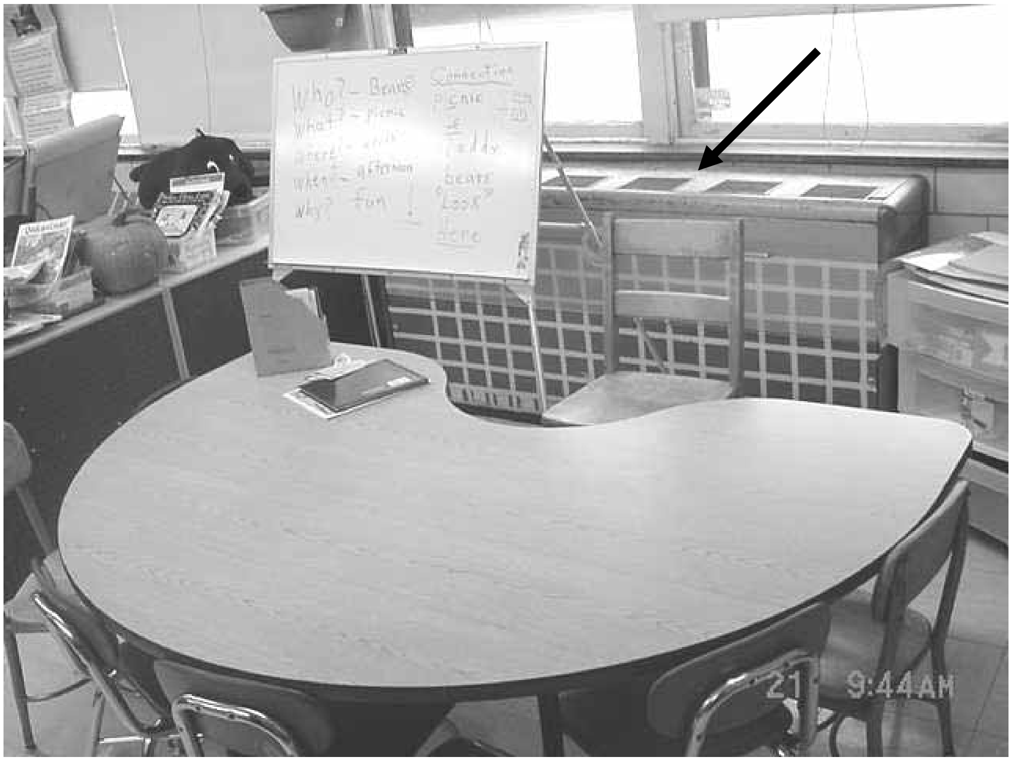
Picture 1



Classroom Univent

Picture 2

Univent Fresh Air Intake

Picture 3

Univent Fan Speed Control, Note That This Unit was Deactivated

Picture 4

Wall-Mounted Exhaust Vent

Picture 5

Wind-Driven Turbine Exhaust System, Note Fan Blades on Top of Unit

Picture 6

Obstructed Wall-Mounted Exhaust Vent

Picture 7

Coat Closet Exhaust Vent, Note Storage of Materials

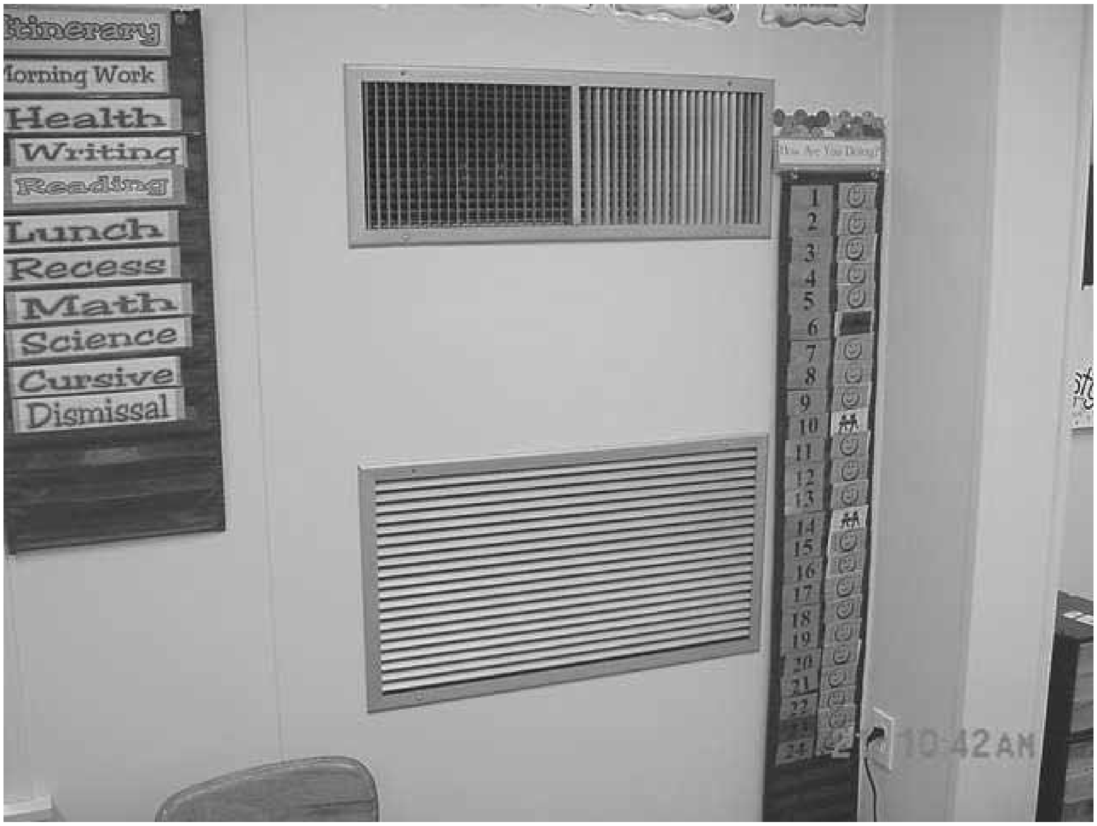
Picture 8

Undercut Coat Closet Doors

Picture 9

Air Handling Unit Mounted on the Exterior of Modular Classroom

Picture 10



Mall-Mounted Supply and Return Vents for Modular Classrooms

Picture 11

Modular Classroom Thermostat, Note Fan Setting on "Auto"

Picture 12

Water-Damaged Wooden Backsplash in Classroom 1

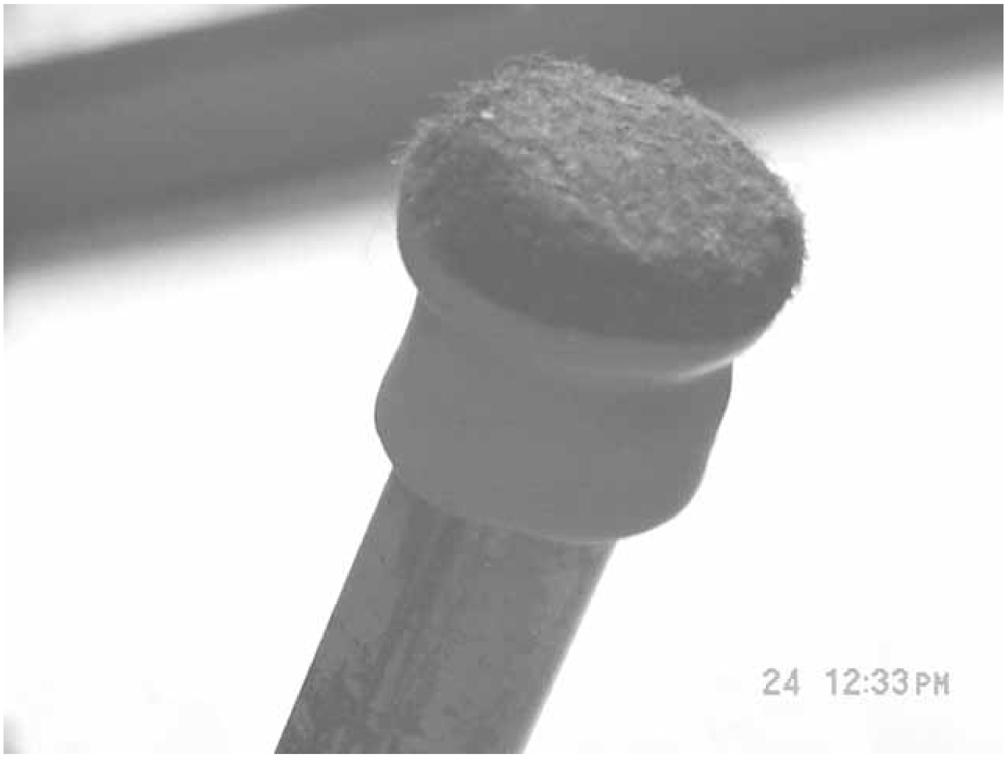
Picture 13

Dusty Filter in Univent

Picture 14

Tennis Balls on Chair Legs

Picture 15



"Glides" for Chair Legs that can be used as an Alternative to Tennis Balls

Allen Avenue School | **Indoor Air Results**

290 Allen Avenue, North Attleborough, MA | **October 21, 2004**

Table 1

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Background (outdoors)	48	47	370	ND	ND	13		-	-	-	Atmospheric Conditions: cool, cloudy, drizzle
Cafeteria/ Gymnasium	74	43	1334	ND	ND	18	100	Y	Y	Y	DO, windows reportedly difficult to open- on capital improvement list
School Psychologist	74	42	1227	ND	ND	5	0	N	N	N	
Reading Office	73	41	949	ND	ND	13	0	Y	N	N	DO
Computer Lab	70	43	320	ND	ND	8	0	Y	Y	Y	DO, DEM
Library	74	47	1338	ND	ND	20	0	Y	N	N	Behind stage area in cafeteria
1	72	55	2044	ND	ND	17	23	Y	Y	Y	Water damaged wooden backsplash/mold growth around sink, DEM, PF, TB

ppm = parts per million parts of air
CT = ceiling tile
AD = air deodorizer
AP = air purifier
CD = chalk dust

µg/m3 = microgram per cubic meter
WD = water damage
DEM = dry erase marker
DO = door open
PC = photocopier

UV = univent
CF = ceiling fan
PF = personal fan
TB = tennis balls
UF = upholstered furniture

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
2	72	38	828	ND	ND	14	21	Y	Y	Y	DEM, PF, TB
3	73	37	716	ND	ND	16	25	Y	Y	Y	DEM, TB
4	73	43	871	ND	ND	13	23	Y	Y	Y	DEM, DO, TB, exhaust vent obstructed by clutter
5	71	47	1520	ND	ND	20	25	Y	Y	Y	DEM, TB, UV deactivated
6	70	49	841	ND	ND	12	26	Y	Y	Y	DEM, TB, stuffed animals, UV obstructed by clutter
7 (Portable)	74	48	2971	ND	ND	25	24	Y	Y	Y	Thermostat fan-auto, DEM
8 (Portable)	75	49	3659	ND	ND	30	20	Y	Y	Y	DEM

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									Supply	Exhaust	
K	77	39	1160	ND	ND	20	1	Y	Y	Y	UV-deactivated, DEM, DO
Nurse's Office	73	40	1079	ND	ND	9	1	Y	N	N	
Resource Room	74	40	994	ND	ND	8	0	N	N	N	DEM, AP
Computer Room	80	45	969	ND	ND	11	0	Y	N	N	Window AC
Main Office	75	39	955	ND	ND	11	1	Y	N	N	Window AC, PC
Principal	74	41	1013	ND	ND	16	2	Y	N	N	Window AC, DO
Teacher's Lounge	74	42	1579	ND	ND	14	4	Y	N	N	Window AC, DEM, DO

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